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GB 2258714 A GB 2253027 A GB 2112506 A
US 4749004 A

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INT CL[5] F16K 11/10 11/20 11/22 11/24

(54) **Diverter valve**

(57) A diverter valve 26 switching a flow of powder material between a return conduit and a delivery conduit consists of a body 40 having a bifurcated internal passage 42 leading from one inlet 28 to two outlets 24, 32. Each of the two outlet branches pass through a chamber 44, 46 via an elastic sleeve 48, 50 which may be selectively pinched, upon application of fluid pressure into a port 52 or 54, to stem flow in the branch. The valve can be connected to a plasma spray head 12 to avoid material waste by stemming material flow when the plasma gun is off-target.

Fig.3.

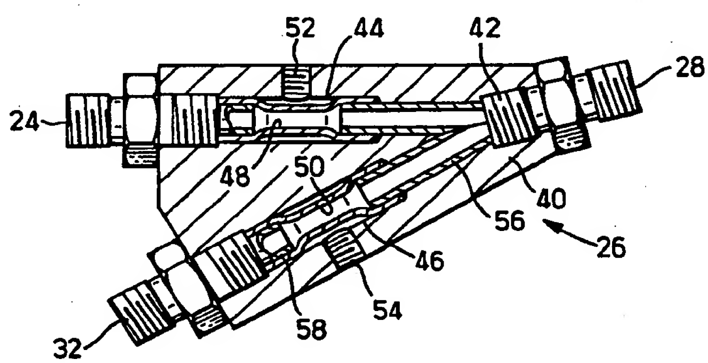

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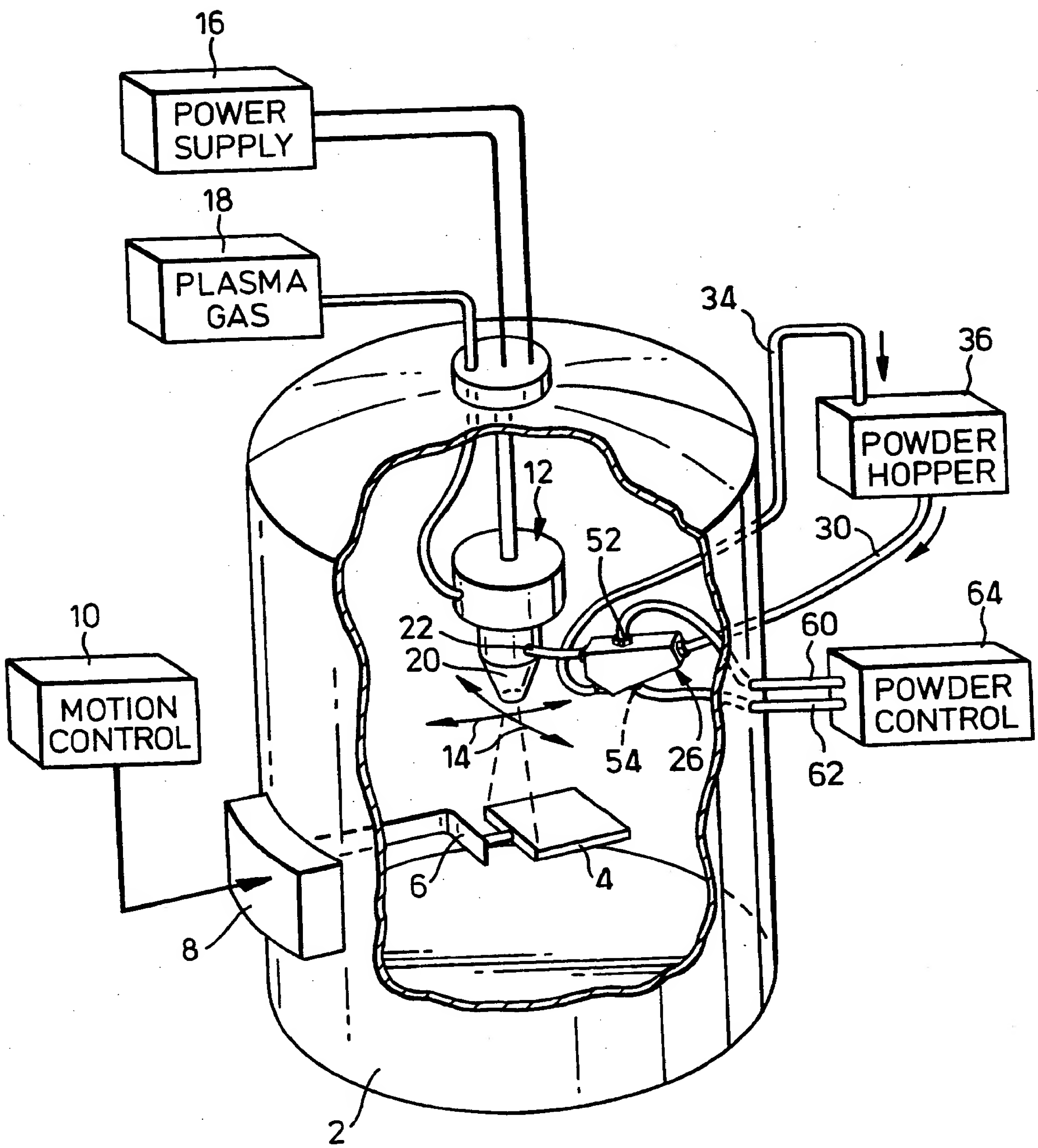
Fig.1.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POWER SUPPLY
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POWDER HOPPER
12
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MOTION CONTROL
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POWDER CONTROL
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Fig.2.

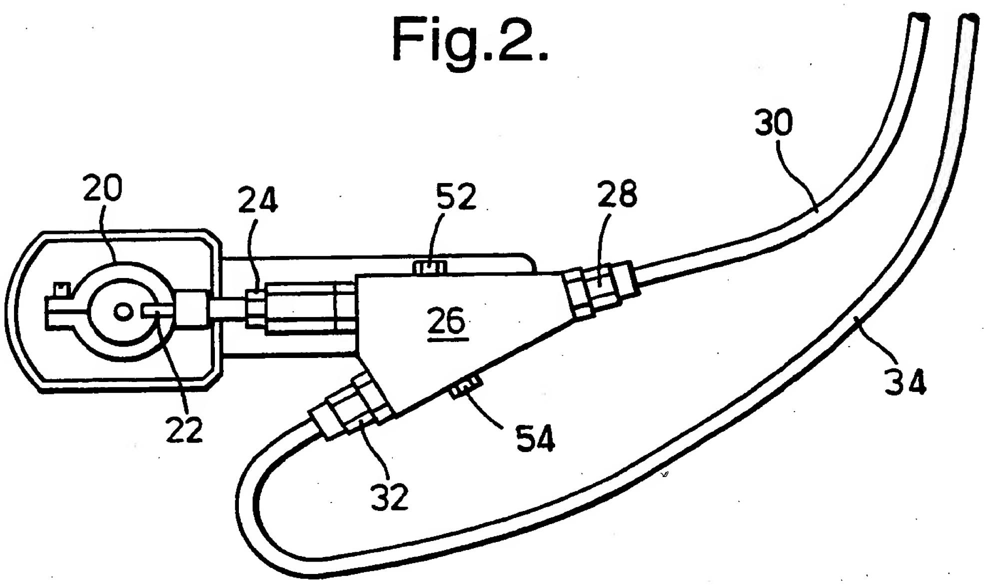
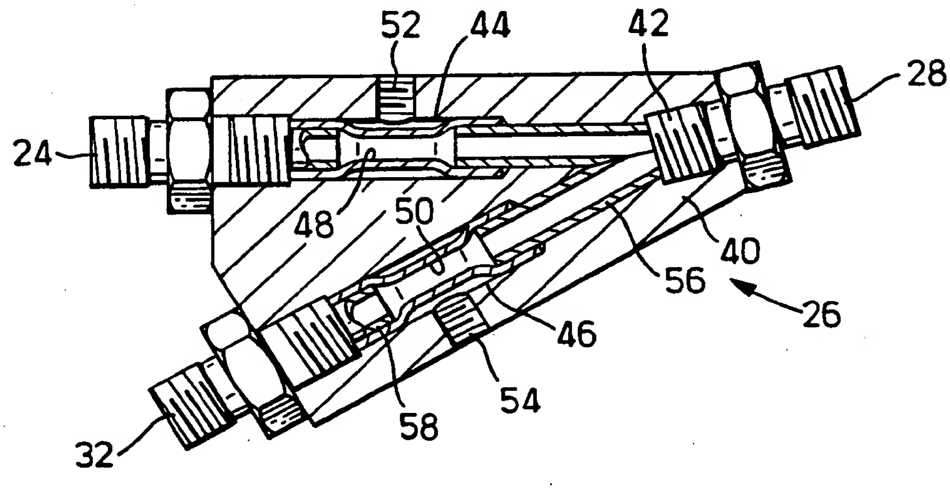
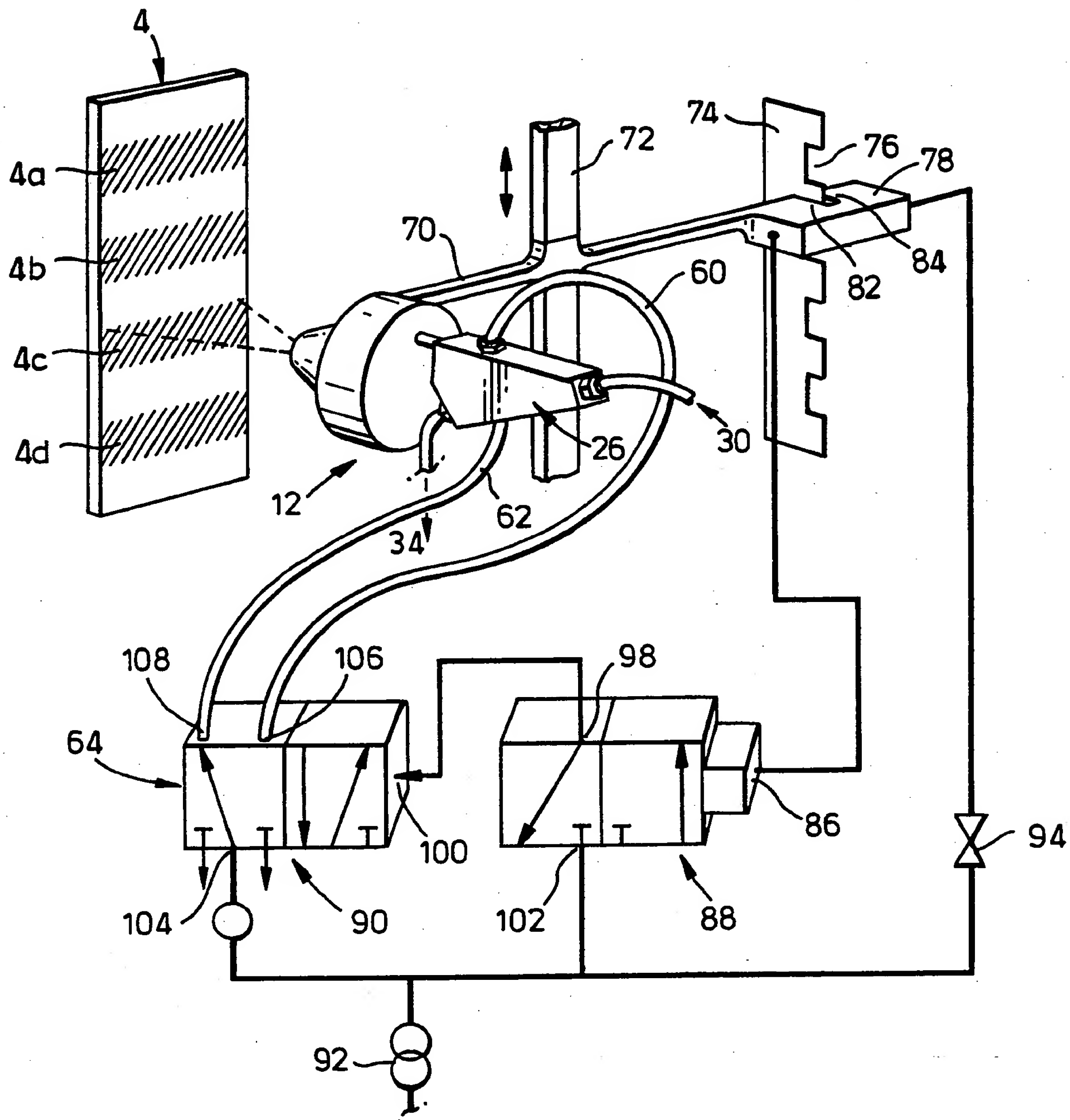


Fig.3.

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4c
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Fig.4.

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DIVERTER VALVE

The invention relates to a diverter valve. In particular the invention concerns a valve useful to switch a flow of fluid, in particular, powder material between flow paths while maintaining source flow.

The invention is found especially useful in plasma and thermal spray systems. A significant amount of powder consumed in plasma and thermal spraying could be saved by interrupting the flow of powder to the gun during "off-target" operation. For example, powder is wasted at start-up, when the gun is driven past an end or edge of a target component at traverse direction reversals, and when it passes over masked regions.

In a typical plasma spray system there is a delay of about 10 to 15 seconds after the commencement of powder supply from the powder feed hopper until full stable flow is attained at the point of injection into the plasma gun arc. Therefore it is not desirable to attempt to save powder by turning off the powder supply. Thermal spray systems suffer the same problem.

The present invention is intended to overcome these drawbacks. It solves the problem of how to maintain a steady powder flow necessary to produce a consistently good quality spray finish while, at the same time, reducing powder consumption by diverting powder from the gun and returning it to a powder feed hopper or a collection hopper for subsequent re-use.

According to the invention there is provided a diverter valve for use in diverting a fluid between flow paths comprising a hollow valve body the interior of which is

formed with plurality of flow conduits including an inlet conduit and first and second outlet conduits, and valve means in each outlet conduit operative in response to an external control signal to stem flow through the flow conduit.

Preferably, the valve means operative to stem flow through an outlet conduit is responsive to a control signal pressure and may comprise an elastic sleeve passing through a chamber which may be pressurised by a control signal to pinch together the sleeve walls to stem flow along the conduit.

One way of carrying the invention into practice will now be described in detail with reference to an embodiment of the invention illustrated in the accompanying drawings, in which:

Figure 1 illustrates a layout of the essential parts of a typical plasma arc spray gun,

Figure 2 illustrates powder feed arrangement to the plasma gun incorporating a powder diverter valve of the present invention,

Figure 3 shows detail of the construction of the diverter valve, and

Figure 4 shows, in part schematic form, a pneumatic powder flow control system.

Referring now to the accompanying drawings, Figure 1 illustrates by way of example a plasma spray system embodying the invention. It will be understood, however, that the arrangements described may apply directly or with minor modification only to a thermal spray system.

The illustrated system comprises a vacuum tank 2 which defines a sealed chamber within which plasma spraying is carried out. Within chamber 2 a workpiece 4 is held by a manipulative robot arm 6 mounted in the wall of the chamber by mounting 8 and controlled by a motion control unit 10. The mounting 8 is positioned at a convenient location on the wall of the chamber to enable workpiece 4 to be manipulated as necessary within the spray cone of the plasma gun.

A plasma gun generally indicated at 12 is suspended from the roof of chamber 2 in such a way as to provide movement in the directions of arrows 14. In spray systems of this type the gun itself generally is capable of limited movement only and substantially the whole of any relative movement between the gun and the workpiece is provided by the robot arm manipulating the workpiece.

The plasma gun nozzle 12 is typical of its type. The gun includes a pair of internal electrodes (not shown) which are connected to opposite plurality outputs of a high voltage power supply 16. A jet of inert gas from an external gas supply 18 is directed into an arc struck between the high voltage electrodes to produce a jet of high velocity plasma which is ejected through a supersonic nozzle 20 in a downward direction towards workpiece 4. In some systems the jet emerges horizontally.

A supply of particulate material or powder is introduced into the plasma jet through a powder tube 22. The spray powder is vaporised by the plasma arc jet and projected at high velocity towards workpiece 4 where it impinges and adheres to form a surface coating. Essentially thermal spray systems operate in the same way but at a lower temperature.

The powder supply tube 22 is connected directly with an outlet conduit 24 of a diverter valve 26, which is shown more clearly in Figures 2 and 3. The diverter valve has an inlet 28 connected to powder hopper by pipe 30 and a second outlet 32 which is connected by a return pipe 34 to the powder hopper 36.

The construction and internal layout of diverter valve 26 is shown in more detail in Figure 3. The valve comprises a body 40 which may be formed in two halves and joined or constructed as a single piece. Inside the valve body 26 an inlet passageway 42 leads from inlet 28 and is bifurcated. The two branches lead to two valve chambers 44,46 which give into the first and second outlets 24,32 respectively. Each of the valve chambers 44,46 is lined with an elastic sleeve 48,50 and has a further inlet 52,54 midway along its length.

Each of the valve chambers 44,46 is lined with an elastic sleeve 48,50 respectively and has a further inlet 52,54 midway along its length. The sleeves 48,50 seal against the chamber walls at their upstream and downstream ends.

With reference to one the valve passageways of the embodiment illustrated in Figure 3 the upstream passageway from the bifurcated inlet 42 is formed by an inlet tube 56 which projects a short distance into chamber 46. The valve chamber is formed with cylindrical walls the diameter of which is slightly greater than the outside diameter of the tube 56. The upstream end of elastic sleeve 50 is secured to the outside of the projecting end of tube 56 and may be trapped between the tube and the chamber wall for secure sealing. A similar arrangement is present at the downstream nd of the chamber where an outlet tube 58 projects a short distance into chamber 46 and the downstream end of sleeve 50 is

secured to its outer surface and may b trapped between the tube and the chamber wall.

The inlet port 54 communicates with the interior of chamber 26 on the outside of sleeve 50. As the upstream and downstream ends of the chamber are sealed by the tubes 56,58 and the ends of sleeve 50, fluid pressure applied through port 54 acts directly on the outer surface of the sleeve. Since the sleeve is elastic it will respond to applied pressure to constrict, and ultimately, to close-off the internal passageway thus stemming the flow of material through the sleeve.

Sleeve 48 located in the chamber 44 in the outer branch of the diverter valve is constructed in identical fashion. As a result pressure may be applied through port 52 to constrict elastic sleeve 48 and, thereby, to stem material flow through that branch of the diverter valve.

As shown in Figure 1 the ports 52,54 are connected by means of respective pipes 60,62 to a powder control unit 64 external of the vacuum chamber 2. In this example diverter valve control is by means of pneumatic pressure and control unit 64 includes a source of pneumatic pressure (not shown) and sequencing controls (not shown). Thus, in use, powder flow entering the valve through inlet 28 may be diverted to either branch leading to first outlet 24 or second outlet 32, by application of pneumatic pressure to the chamber of the opposite branch thereby stemming flow therethrough.

The sequence of operations at start-up, in normal use, is that an arc is struck between the electrodes within plasma gun 12 by a high voltage produced by power supply 16 and a plasma jet produced by injecting gas from source

18. Then powder material from hopper 36 is supplied through supply conduit 30 to the powder tube 22 just downstream of plasma supersonic nozzle 20. As previously mentioned, it may take several seconds and as many as 10-15 seconds, to obtain a constant powder flow rate from hopper 36 through supply conduit 30 and to establish a stable plasma spray pattern. Inevitably the powder supplied during a period of unstable plasma operation is therefore lost. Also when the plasma gun has to reverse its traverse relative to the workpiece being treated, in order to avoid unnecessary accumulation of sprayed material deposited on the workpiece the spray is usually directed "off-target". Furthermore, it may be wished to leave areas of the workpiece uncoated and, again, to avoid the problems associated with stopping and starting powder flow these areas are normally masked rather than interrupt the powder flow. In these cases useful powder is used up and effectively wasted by directing the plasma spray off-target rather than interrupting powder flow.

The present invention, however, makes it possible to avoid these drawbacks by establishing or maintaining a stable flow rate without powder loss. Normally during periods of gun operation which would result in uneven powder coating the gun is directed away from the workpiece and powder supplied during those periods is inevitably lost. However, according to the invention powder flow is diverted from the gun into a secondary conduit which returns unused powder to the supply hopper or to a separate collection tank.

Typically the supply hopper may be pressurised during powder flow. A fluidising system may be used to keep powder in the hopper in a free flowing state whereby it may be delivered into the supply conduit at a controlled

rate by a metering valve, not shown on the illustrated arrangement. In such a system it may be preferable to switch diverted flow to a separate collection tank form whence it may be returned to the supply hopper later.

Preferably the diverter valve 26 is located close to the plasma gun to minimise the length of conduit between the diverter valve and the delivery outlet of tube 22.

Control pressure is applied to control parts 52,54 in the valve 26 alternatively; that is in a two branch system one or the other of the branches, but only one, is always constricted and the alternate unconstricted during operation. In this way powder movement is maintained at all times and at all places in the system right up to the final delivery nozzle into the plasma jet. However, waste is kept to a minimum since the powder is introduced into the plasma only when needed. By keeping powder circulating through the remainder of the delivery system it is not allowed to settle and compact either in the system of delivery conduits or in the hopper.

Preferably, the control pressure signals applied to valve control ports 52,54 are tailored to cut-off powder flow sharply. Ideally the pressure waves to both ports are steep-sided and closely synchronised to maintain a steady powder flow rate, particularly when flow through outlet 24 and delivery tube 22 is re-established. A cut-off pressure signal may be "over-pulsed" at its leading edge to provide as sharp a cut-off as possible. Preferably, the pneumatic gas used to operate the diverter valve is an inert gas such as argon so that in the event of leakage quality of the sprayed coating is not compromised.

Figure 4 shows a diagram of a pneumatic powder flow control system, in part-schematic format, adapted to produce a banded spray pattern. Where appropriate parts shown in the previous figures of the drawings carry like references. Thus, there is shown a workpiece 4 on a surface of which a spray coat pattern comprising horizontal bands 4a, 4b, 4c and 4d is to be produced. The plasma gun 12 is carried a vertically traversing mechanism 70 which is capable of being driven up and down as indicated by direction arrows 72. As before, coating powder is supplied to gun 12 via supply pipe 30 and through diverter valve 26 under the control of pneumatic pressure on control pipes 60,62.

Attached to the plasma gun 12 so that is traverses with it is a control strut 74 disposed in a vertical plane parallel to the direction of movement of the gun as indicated by arrows 72. One vertical edge 76 of strut 74 is formed with a profile corresponding to the coating bands 4a-4d required on the workpiece. That is, the profiled edge 76 is formed a series of square-edged cut-outs, the mark-to-space ratio of which matches the desired banding profile.

A sensor means 78 is positioned adjacent the profiled edge 76 of strut 74 in a fixed location so that as the gun 12 traverses the sensor is capable of detecting the passage of the profiled edge. In the pneumatic system of the present example the sensor means 78 comprises a pneumatic sensor, consisting of a C-shaped member the limbs of which are located on opposite sides of strut 74, thereby defining a gap through which the profiled edge 76 moves during the passage of gun 12.

The pneumatic sensor means is operative to detect pneumatic pressure across a sensing gap 80 provided

betwe n the confronting end faces at th nds of links of the C-shaped member. The sensor means 78 is connected in a pneumatic circuit which includes a small air pressure delivery nozzle 82 in one limb end face opposite a sensing port 84 in the opposite end face. Thus, in operation, sensor indication is dependent upon whether or not a small pneumatic jet emitted by nozzle 82 reaches port 84 or is deflected by an intervening object. In the example the profiled edge of strut 74 is arranged to pass through the gap 80 so that the square-ware profile is sensed as the strut together with the gun 12, is traversed vertically.

The sensing means 78 is connected in a pneumatic sensing circuit form sensing port 84 in series with a pneumatic amplifier 86 and spool valves 88,90. The spool valves provide alternative switch connections according to the position of the valve spool. The connections are shown in schematic diagrams on the forward sides of the rectangles 88,90 in the drawing. A source 92 of pneumatic pressure is connected to the valves 88,90 and to the sensing means 78 through a gate valve (on/off isolator) 94.

The sensing port 84 is connected via a length of tubing 96 to a pneumatic amplifier 86 which drives a control input of a first of the spool valves 88. A pressure outlet port 98 leading from spool valve 88 is connected to a control input 100 of a second of the spool valves 90. A pressure input port 102 of valve 88 is connected to the pressure source 92. The spool valve 90 also has a pressure input 104 connected to the pressure source 92 and has two pressure output port 106,108 to which the tubes 60,62 controlling the div rter valve 26 are connected.

In operation, when one of the projections on strut 74 passes through the sensing gap of sensing means 78 a pressure input to amplifier 86 is absent and the first spool valve 88 occupies a rightwards (in the drawing) position in which the pressure input port 102 is isolated from the output 98, as indicated by the position of the corresponding schematic. In turn, this results in an absence of pressure at the control input 100 for the second spool valve 90 which therefore also occupies a rightwards position. In this position the pressure at input port 104 is connected to outlet port 108 which has the effect, referring back to Figure 3, of cutting off flow into the powder diversion tube 34. Meanwhile, the second spool valve outlet port 106 to which tube 60 controlling powder flow through the diverter valve 26 to the plasma gun is vented to atmosphere. The result is that powder is fed into the plasma jet and a band of coating is sprayed onto the workpiece 4.

As the plasma gun 12 is traversed the strut 74 moves through the sensing gap 80 of sensing means 78. When a cut-out portion of the profile passes through the gap a jet of pressurised fluid from nozzle 82 to able to reach port 84 as a result of which pressure is applied to the amplifier 86 at the input of first spool valve 88. The spool moves leftwards establishing the connections indicated in the right most schematic box, according to which communication is made between the pressure input port 102 and the pressure output port 98. Operating is now applied, in turn, to the second spool valve also moving it leftwards establishing the connections of the right most schematic box. This reverses the connections to the outlet ports 106 and 108 so that pressure at inlet port 104 is not connected to outlet port 106 and tube 60 while port 108 and tub 62 are vented to atmosphere. The constricting valve in the plasma gun line of diverter

valve 26 is now energised to st m powder flow to the plasma gun from tube 30 while the corresponding valve in the diverted line is released to carry diverted powder flow into tube 34. As a consequence stemmed so that no coating is deposited although the plasma arc in the gun continues operation.

As the plasma gun continues its traverse and another "blanking" profile section passes through the sensing gap 80 powder flow is re-established and coating deposition of a further band is begun. The deposition of spray coating is thus controlled by the profile of the strut 74 and with the mark-to-space profile thereon.

It will be appreciated by readers skilled in the appropriate field that controlled of the plasma gun and diverter valve may be arranged in other ways. For example, the pneumatic sensing means 78 of the above example could be replaced by optical sensing means wherein the spool valves 88,90 could be replaced by electronically controlled valves, if a pneumatic diverter valve is retained.

In a still further example control of the operation of the diverter valves may be derived from instructions stored in electronic memory and synchronised with movement of the gun relative to the workpiece.

Other forms of valves may be utilised for example with mechanical shutters or some form of movable constriction means and may be operated by any suitable means: pneumatic, hydraulic, electrical or mechanical.

Also, it is to be understood that although the diverter valve of the illustrated embodiment has one inlet and two outlets more complicated feed and distribution

arrangements are contemplated. For instance, there may be a plurality of inputs for different material flows with each flow being selectively returned via its own return line until switched through to the final delivery nozzle.

Furthermore, although described with reference to an embodiment utilising a vacuum chamber the invention may be applied just as well, with appropriate modifications as necessary, to a system of air spraying.

CLAIMS

1 A diverter valve for use in diverting a fluid between flow paths comprises

a hollow valve body the interior of which is formed with a plurality of flow conduits including an inlet conduit and first and second outlet conduits,

valve means in each outlet conduit operative in response to an external control signal to stem flow through the flow conduit.

2 A diverter valve as claimed in claim 1 wherein the valve means operative to stem flow through a conduit is responsive to control signal pressure.

3 A diverter valve as claimed in either claim 2 or claim 2 wherein the valve means comprises a chamber having elastic walls which can be pinched together by the control signal pressure.

4 A diverter valve as claimed in any preceding claim wherein the valve means comprises an elastic sleeve housed within a pressure chamber.

5 A plasma or thermal spray system including a plasma or thermal spray gun having means for delivering a supply of powder material from a source thereof into the gun further including a diverter valve for selectively diverting the powder material away from the gun.

6 A plasma or thermal spray system as claimed in any preceding claim further comprising means for returning diverted material to the source thereof.

7 A plasma or thermal spray system as claimed in any prceding claim wherein the diverter valve is located close to the gun.

8 A system as claimed in any preceding claim further including control means for controlling actuation of the diverter valve.

9 A system as claimed in claim 8 wherein the control means is responsive to the position of the gun relative to a workpiece to stem fluid flow to the gun.

10 A system as claimed in claim 8 or claim 9 wherein the control means further comprises means for producing a control signal profile.

11 A system as claimed in claim 10 wherein the means for producing a control signal profile includes a template formed with an edge corresponding to said profile and means for sensing said edge.

12 A system as claimed in claim 11 wherein the means for sensing the profiled edge comprises a pneumatic sensor.

13 A system as claimed in any one of claims 9 to 12 wherein the control means is adapted to control the position of spool valve means having a plurality of control signal outputs connected to pr ssurise the valve means of the diverter valve.

14 A system as claimed in any of claims 9 to 13 wherein the control means is pneumatically actuated and produces pneumatic control signal outputs to operate the diverter vlave.

15 A diverter valve substantially as claimed with reference to the accompanying drawings.

16 A plasma or thermal spray system substantially as claimed with reference to the accompanying drawings.

Patents Act 1977 **Examiner's rep rt t the C mptroller under Section 17** **(The Search rep rt)**	Application number GB 9406688.3
Relevant Technical Fields (i) UK Cl (Ed.M) F2V (VA3) (ii) Int Cl (Ed.5) F16K 11/10, 11/20, 11/22, 11/24	Search Examiner M SIDDIQUE Date of completion of Search 27 JUNE 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 1-4

Categories of documents

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A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2258714 A	(DRAYTON) page 7 etc, controlled selective opening of ports 3, 4	1, 2
A	GB 2253027 A	(MEDICAL GRAPHICS) pinching valves	3
X	GB 2112506 A	(SHELL) diverter valve	1
X	US 4749004	(BOEING) entire document	1, 2

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